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Abstract

In this paper, the authors develop a new tool to improve the short-term forecasting of real GDP growth in the euro area and Japan. This new tool, which uses unrestricted mixed-data sampling (U-MIDAS) regressions, allows an evaluation of the usefulness of a wide range of indicators in predicting short-term real GDP growth. In line with previous Bank studies, the results suggest that the purchasing managers' index (PMI) is among the best-performing indicators to forecast real GDP growth in the euro area, while consumption indicators and business surveys (the PMI and the Economy Watchers Survey) have the most predictive power for Japan. Moreover, the results indicate that combining the predictions from a number of indicators improves forecast accuracy and can be an effective way to mitigate the volatility associated with monthly indicators. Overall, our preferred U-MIDAS model specification performs well relative to various benchmark models and forecasters.

JEL classification: C, C5, C50, C53, E, E3, E37, E4, E47
Bank classification: Econometric and statistical methods; International topics

Résumé

Dans cette étude, les auteurs présentent l'outil qu'ils ont mis au point afin d'améliorer les prévisions de la croissance du PIB réel à court terme pour la zone euro et le Japon. Ce nouvel outil, qui s'appuie sur un modèle de régression fondé sur un échantillonnage de données de fréquence mixte sans contrainte (U-MIDAS), permet d'évaluer l'utilité d'une vaste gamme d'indicateurs pour prévoir la croissance du PIB réel à court terme. Corroborant les précédentes recherches menées par la Banque, les résultats de l'étude donnent à penser que l'indice des directeurs d'achat se classe parmi les indicateurs les plus performants pour prévoir la croissance du PIB réel à court terme dans la zone euro et que, dans le cas du Japon, les indicateurs de la consommation et les enquêtes réalisées auprès des entreprises (indice des directeurs d'achat et enquêtes auprès des observateurs de l'économie) ont le meilleur pouvoir prédictif. Les résultats montrent par ailleurs que la combinaison des prédictions tirées de plusieurs indicateurs améliore l'exactitude des prévisions et peut être un moyen efficace d'atténuer la volatilité associée aux indicateurs mensuels. Dans l'ensemble, la spécification du modèle U-MIDAS que les auteurs privilégient donne de bons résultats, par comparaison avec les prévisions de référence issues d'un groupe de modèles et de prévisionnistes.

Classification JEL : C, C5, C50, C53, E, E3, E37, E4, E47
Classification de la Banque : Méthodes économétriques et statistiques; Questions internationale

1 Introduction

To support Canadian monetary policy decisions, the Bank of Canada's International Economic Analysis Department closely monitors short-term developments in a number of foreign economies, including the United States, the euro area, Japan, China and several emerging economies. The traditional challenge analysts face when monitoring short-term forecasting for a given country or region in real-time is that important indicators of economic activity, such as quarterly real GDP, are typically released with a significant lag (generally 30 to 60 days). To circumvent this challenge, analysts usually track timelier and higher-frequency indicators, including monthly business surveys and measures of real activity such as industrial production or retail trade. To map movements in these indicators into real GDP growth space, a number of short-term forecasting models have been developed in the academic community, and among private and central banks, including at the Bank of Canada.[1]

This paper proposes an unrestricted mixed-data sampling (U-MIDAS) model for short-term forecasting of real GDP growth in the euro area and Japan. This new tool allows us to evaluate the usefulness of a wide range of indicators when predicting short-term growth in real GDP. In line with previous Bank studies, we find that the purchasing managers' index (PMI) is among the best-performing indicators to forecast real GDP growth in the euro area, while consumption indicators and business surveys (the PMI and the Economy Watchers Survey) have the most predictive power for Japan. Moreover, we find that combining the predictions from a number of indicators improves forecast accuracy and can be an effective way to mitigate the volatility associated with monthly indicators. The model performs well relative to various benchmark models and forecasters.

The remainder of the paper is organized as follows. In section 2, we review some literature on short-term forecasting models and present the specification of our regression model. Section 3 discusses the data used in our forecasting exercise. Sections 4 and 5 present the results of our out-of-sample forecast evaluation and forecast combination exercises, respectively. Section 6 compares the performance of our short-term forecasting model against various benchmarks and looks at some extensions. Section 7 concludes.

2 Methodology and related literature

2.1 Models for short-term forecasting

Short-term forecasting tries to exploit the information contained in various high-frequency indicators, which are typically published earlier than key macroeconomic data such as GDP. As such, forecasts of short-term movements in real GDP in real time usually require frequent updates during a quarter as high-frequency indicators are released. A wide range of approaches and models are used by central banks to forecast output in a data-rich environment and to handle the ragged-edge nature of data

[1] Barnett and Guérin (2013) review the short-term forecasting models used at the Bank of Canada for foreign economies.

publications.[2] The Bank of Canada uses two common approaches to forecast real GDP growth in the euro area and Japan: factor models and a set of bridge equations.[3]

Factor models:

Factor models efficiently condense the information contained in a large pool of indicators into a relatively small number of common factors, which helps practitioners to distill information on the state of the economy from a wide range of indicators. More specifically, in a factor model, the data are split into a common component and an idiosyncratic component. The common component is a linear combination of common factors that is responsible for co-movements between the variables in the data set. The idiosyncratic component can be interpreted as measurement error, or sector-specific or variable-specific shocks. Usually the factors are modelled in a dynamic fashion following a vector autoregressive (VAR) model. Note that the factors as well as their associated loadings are not observed in practice and have to be estimated from the data:[4]

$$Y_t^{(Q)} = \Lambda F_{\mathrm{t}}^{(\mathrm{Q})} + \epsilon_t \qquad (1)$$

$$F_{\mathrm{t}}^{(\mathrm{Q})} = \sum_{t=1}^{p} A_p F_{\mathrm{t-p}}^{(\mathrm{Q})} + \mu_t \qquad (2)$$

where, in equation (1), Λ is the factor loading matrix, F_t is the unobservable factor and Y_t is the dependent variable of interest, both expressed at frequency Q. Equation (2) describes the dynamics of the factors modelled as a VAR model with p lags.

Bridge equations:

In bridge equations, the mixed-frequency problem is solved by first forecasting missing observations for the monthly indicators and then aggregating the monthly observations to get a quarterly value for that indicator. Quarterly GDP is then regressed on the actual and predicted quarterly indicators.

An important drawback of both factor models and bridge equations is that they usually require a prediction for missing values of the monthly indicators. These predictions can be obtained using various methods, including the expectation maximization algorithm and univariate monthly autoregressive (AR) models, or by simply assuming a constant reading for the remainder of the quarter.

[2] See Bańbura et al. (2013) for an extensive discussion of the main approaches to short-term forecasting in real-time.

[3] The factor model used at the Bank for the euro area is based on the work of Lombardi and Maier (2012), while for Japan, the factor model is based on the work of Godbout and Lombardi (2012). Bridge equations used at the Bank are similar to those in Zheng and Rossiter (2006), Rossiter (2010), and Angelini et al. (2011). The Bank also uses alternative models to forecast GDP growth in the euro area and Japan.

[4] In the factor model literature, factors have been estimated using principal-component methods or maximum-likelihood-based methods using the Kalman filter.

2.2 The MIDAS and U-MIDAS approaches

An alternative framework, which we use in this paper, is mixed data-sampling (MIDAS) models. The distinguishing feature of MIDAS models is that the predictors are included in the regression at the original observation frequency. In particular, MIDAS models relate low-frequency variables, such as quarterly GDP growth, to lags of high-frequency variables, such as monthly, weekly or even daily indicators. Since the number of lagged coefficients to estimate is often very large (especially with daily data), a pre-defined functional form for the lag structure of the indicators is usually imposed to reduce the number of parameters to estimate. The basic MIDAS model with a single explanatory variable takes the following form:

$$Y_t^{(l)} = \beta_0 + \beta_1 B(L^{1/h};\theta)X_t^{(h)} + \epsilon_t \tag{3}$$

where $Y_t^{(l)}$ is the lower-frequency variable (e.g., quarterly). $B(L^{1/h};\theta)$ is the lag polynomial (with the lag structure represented by the parameter θ) of the high-frequency indicator $X_t^{(h)}$ (e.g., monthly, h = 3).

By reducing the number of parameters to estimate to three (β_0, β_1 and θ), the use of a functional form for the lag structure simplifies the estimation of MIDAS models considerably. The most commonly used functional form for short-term forecasting is the Almon polynomial, which gives more weights to more recent observations.[5] The two-parameter $(\theta_1;\theta_2)$ version of the exponential Almon lag polynomial yields the following weighting scheme for the various months (w_m) when used in a monthly/quarterly framework:

$$w_m(\theta_1;\theta_2) = \frac{e^{(\theta_1 m+\theta_2 m^2)}}{\sum_{m=1}^{k} e^{(\theta_1 m+\theta_2 m^2)}} \tag{4}$$

While imposing a specific functional form reduces the number of coefficients to estimate, it either requires a strong knowledge of the dynamics of the data or may represent a strong assumption for characterizing the data-generating process. An alternative MIDAS approach, often referred to as unrestricted MIDAS (U-MIDAS), does not impose a specific functional form on the lag structure, but does assume linearity.[6] A U-MIDAS model can be written:

$$Y_t^{(Q)} = \beta_1 + \varphi_1 Y_{t-1}^{(Q)} + \cdots + \varphi_p Y_{t-p}^{(Q)} + \sum_{j=1}^{3} \gamma_{1,j} X_t^{(M_j)} + \cdots + \sum_{j=1}^{3} \gamma_{q+1,j} X_{t-q}^{(M_j)} + \omega_t \tag{5}$$

[5] The use of MIDAS regressions and the exponential Almon polynomial to forecast economic and financial variables has been documented extensively, and several studies found MIDAS regressions to be an effective way to exploit timely and high-frequency variables for short-term forecasting. See Clements and Galvão (2008, 2009) and Ghysels, Sinko and Valkanov (2007).

[6] Foroni, Marcellino and Schumacher (2011) show that U-MIDAS generally outperforms the standard MIDAS when mixing quarterly and monthly data, which could reflect the fact that when the number of lags to estimate is relatively small, the estimation problems associated with the curse of dimensionality are more limited.

where $Y_t^{(Q)}$ is a quarterly variable of interest, and $X_t^{(M_j)}$ is a monthly indicator. In equation (5), the dependent variable is assumed to follow an $AR(p)$ process, while q lags of the explanatory variable are also included.

2.3 Forecasting model specification

The forecasting tool introduced here uses single-indicator, unrestricted MIDAS (U-MIDAS) regressions to predict real GDP growth in the euro area and Japan for up to two quarters ahead (i.e., a "nowcast" of the current quarter and a forecast). With only one indicator in each regression and a limited number of lags, the coefficients in equation (5) can be estimated without losing too many degrees of freedom. Also, in U-MIDAS, the weights given to each individual month are entirely data driven, reflecting the idea that each month of data is not equally important in forecasting GDP.[7] Another interesting feature of U-MIDAS for short-term forecasting is that, unlike other approaches such as factor models or bridge equations, it does not require a forecast of missing months and therefore does not require any assumptions about the behaviour of the indicators in the upcoming months.

The MIDAS model literature suggests various approaches to selecting the lag structure of the independent variables. Foroni, Marcellino and Schumacher (2011) use the Bayesian information criterion (BIC), while Koening, Dolmas and Piger (2003) use a constant specification with five lags of the monthly variables. Our U-MIDAS specification includes six lags of the monthly indicators, i.e., three months of data covering the quarter for which we observe the last value of real GDP growth and the three months of data covering the first quarter to forecast, provided they are available.[8] As the different monthly values of the indicators are released throughout a quarter, the specification of the regression model changes slightly. Let $X_t^{(M_1)}$, $X_t^{(M_2)}$ and $X_t^{(M_3)}$ be monthly indicators in the first, second and third month of quarter t, for which we are producing a nowcast of $Y_t^{(Q)}$ (real GDP growth in quarter t). Said differently, $X_t^{(M_1)}$ is a quarterly time series consisting of all first monthly values of an indicator *X* for each quarter over history. Then:

- In month 1, the nowcast model of *Y* consists of a constant, one lag of *Y* and four months of data on indicator *X*:

$$Y_t^{(Q)} = \beta_1^{(M_1)} + \varphi_1 Y_{t-1}^{(Q)} + \gamma_{1,1} X_t^{(M_1)} + \gamma_{2,1} X_{t-1}^{(M_1)} + \gamma_{2,2} X_{t-1}^{(M_2)} + \gamma_{2,3} X_{t-1}^{(M_3)} + \omega_t^{(M_1)} \quad (6)$$

- In month 2, the specification is the same as in month 1, but the second month of the current quarter ($X_t^{(M2)}$) is added to the regression:

$$Y_t^{(Q)} = \beta_1^{(M_2)} + \varphi_1 Y_{t-1}^{(Q)} + \gamma_{1,1} X_t^{(M_1)} + \gamma_{1,2} X_t^{(M_2)} + \gamma_{2,1} X_{t-1}^{(M_1)} + \gamma_{2,2} X_{t-1}^{(M_2)} + \gamma_{2,3} X_{t-1}^{(M_3)} + \omega_t^{(M_2)} \quad (7)$$

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[7] See Cross and Wyman (2011) for a description of how monthly growth rates relate to quarterly growth rates.
[8] A lag length of six months is somewhat arbitrary but was chosen because it includes the most important months likely to affect quarter-over-quarter GDP growth. Moreover, we impose a constant specification across indicators and across time to facilitate the interpretation and comparison of the information content of each indicator.

- In month 3, all three months of the current quarter (t) and previous quarter (t–1) are included (six months of the indicator X in total):

$$Y_t^{(Q)} = \beta_1^{(M_3)} + \varphi_1 Y_{t-1}^{(Q)} + \gamma_{1,1} X_t^{(M_1)} + \gamma_{1,2} X_t^{(M_2)} + \gamma_{1,3} X_t^{(M_3)} + \gamma_{2,1} X_{t-1}^{(M_1)} + \gamma_{2,2} X_{t-1}^{(M_2)} + \gamma_{2,3} X_{t-1}^{(M_3)} + \omega_t^{(M_3)} \tag{8}$$

where $\omega_t^{(M_j)} = \epsilon_t^{(M_j)} + \theta_1 \epsilon_{t-1}^{(M_j)}$ for $j = 1, 2$ or 3. (9)

Our U-MIDAS specification is therefore an $ARMA(1,1)$ of quarterly GDP growth, augmented with lags of a monthly indicator. The $ARMA(1,1)$ specification, which was found to be the best autoregressive model for real GDP growth, helps to capture the persistence in both real GDP growth and the residuals.[9]

The equation set-up for the forecast of the following quarter (t+1) is exactly the same as the set of equations presented above, except that the dependent variable is real GDP growth at quarter t+1 ($Y_{t+1}^{(Q)}$) rather than quarter t.[10]

3 The macroeconomic indicator data

We consider a wide selection of indicators covering the euro area and Japan. These indicators range from survey data, to hard macroeconomic indicators, to labour market or financial variables. Overall, we consider 72 indicators for the euro area and 74 for Japan. When needed, series are transformed to be stationary based on an augmented Dickey–Fuller (ADF) unit root test. Appendix 3 provides a comprehensive list of the variables considered in this project and the transformation applied (if necessary). Most of these data series are available from January 1999 onward.

Survey data are among the most important indicators used in our forecasting exercise, mainly because they have the advantage of being very timely in comparison to hard data. The purchasing managers' index (PMI) is a diffusion index where the respondents, usually senior executives in various industrial sectors, provide information regarding many aspects of their business activities. Numerous studies undertaken in recent years have shown that PMIs are very useful at forecasting real GDP growth (Godbout and Jacob 2010; Rossiter 2010). We evaluate many subcomponents coming from the PMI survey, as well as some price-adjusted versions of PMI subcomponents (see Appendix 2). We also consider other important surveys, including the European Commission's Economic Sentiment Indicator (ESI) and the Economy Watchers Survey from Japan's Cabinet Office.

[9] The lag structure of the autoregressive moving average (ARMA) was selected based on the in-sample information criterion (BIC) and out-of-sample forecast performance. Some results of a sensitivity analysis of the choice of the ARMA structure are presented in Section 6.1.

[10] Appendix 1 provides an example of the U-MIDAS specification in real time with the PMI.

4 Which indicators perform best at forecasting short-term growth in real GDP?

In this section, we present the results of a pseudo out-of-sample forecasting exercise using the U-MIDAS model described in section 2 to determine the indicators that best predict short-term real GDP growth in the euro area and Japan.

4.1 The forecasting exercise

We set up a forecasting evaluation exercise in which we compare pseudo out-of-sample predictions of quarter-over-quarter real GDP growth obtained using the U-MIDAS model and realized values.

First, a pseudo real-time data set is assembled using final-vintage data (as of 2013Q1), but truncated to contain only observations that would have been available when the forecast would have been made in real time (ragged-edged in nature).[11] Second, we estimate the U-MIDAS regression models using the pseudo real-time data set over the sample from 1999Q1 to 2009Q4, and forecast real GDP growth two quarters ahead. Using an expanding window approach, we obtain out-of-sample forecasts between 2010Q1 and 2013Q1.[12]

Finally, we calculate the forecast errors by comparing our pseudo real-time forecasts of real GDP growth against actual realizations.[13] We present the forecast evaluation results calculated over the 2010Q1–13Q1 period using two different methods: the predictions' root mean square error (RMSE); and the percentage of time that the model correctly predicts the direction of growth (an increase or decrease in real GDP growth), also known as the "hit ratio." In the following sections, we report quarterly averages of the evaluation statistics, for both the current and next quarters.[14]

4.2 Forecast evaluation results for individual indicators[15]

4.2.1 Euro area

Figures 1a and 1b show the RMSEs calculated for the euro-area indicators, for the forecasts of the current and next quarters, respectively. The horizontal axis displays the RMSEs (expressed in percentage points), while the vertical axis groups indicators by category. Each circle on these graphs represents the RMSE of one specific indicator; for instance, in the PMI row, there are multiple circles corresponding to all subcomponents of the PMI survey, including price-adjusted PMI. The circles in red represent some of

[11] In section 6.1, we present a sensitivity analysis of our results using a real-time GDP series.

[12] The start date (1999Q1) was determined by the availability of PMI data, which start in mid-1998. The estimation period end date (2009Q4) was chosen to exclude the Great Recession (2008–09) from the forecast evaluation sample, because this period is considered atypical and including it may affect the ranking of the indicators in a way that may not be optimal if upcoming years are more similar to 2010–12 than to 2008–09. Nevertheless, in section 6.1, we look at the sensitivity of our ranking by including 2008–09 in the forecast evaluation period.

[13] The actual realizations are taken ex post (as of 2013Q1), i.e., we use the final vintage of data as the "true" GDP growth, since we wish to abstract from measurement errors that could affect early estimates of real GDP growth.

[14] With monthly data, the model forecasts are updated three times during a quarter and so are various evaluation statistics.

[15] All numerical results presented in this section are available in Appendix 4.

the best-performing indicators (those with the lowest RMSE). Figures 2a and 2b show the hit ratios for the current and next quarters, respectively. The indicators identified as performing best in terms of RMSE remain highlighted in red.[16]

Figure 1. Euro area: Individual-indicator RMSE

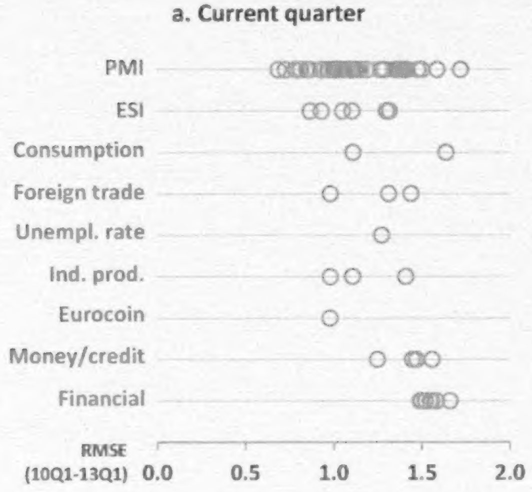
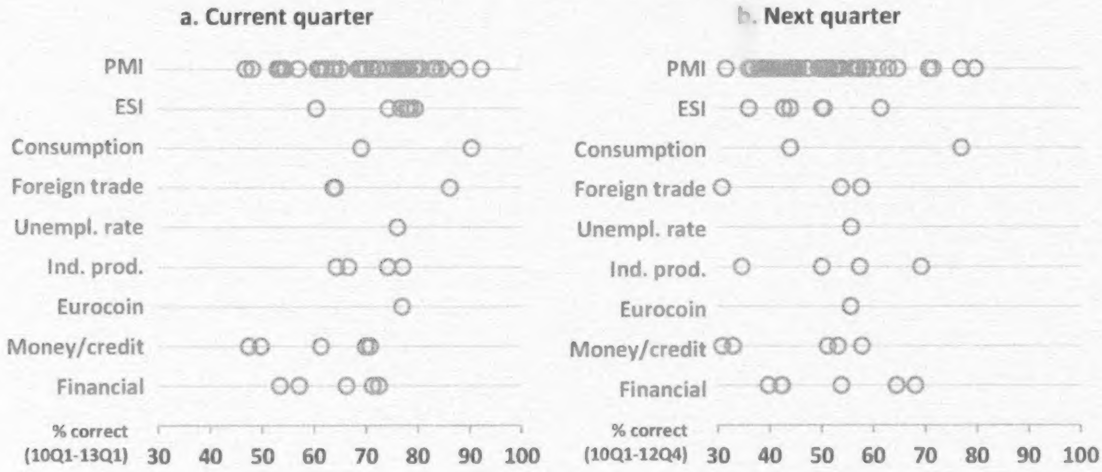


Figure 2. Euro area: Individual-indicator "hit ratio"
(% of time direction of GDP is correctly predicted)



Our RMSE results indicate that the best indicators to predict current quarter euro-area GDP growth, over 2010 to 2012, are some PMI components (including prices-adjusted PMIs) and ESI components, the aggregate industrial production index, and Eurocoin (a monthly GDP growth estimate produced by the

[16] The selection of the top indicators for forecasting GDP growth in the current and next quarter is based primarily on RMSEs, and the hit ratio is used mainly as a confirmation of this selection.

central bank of Italy). These four sets of indicators are also some of the best performers during an evaluation period that includes the Great Recession (2007–12). In contrast, growth in real imports, which shows relatively good forecast accuracy over the 2010Q1–13Q1 period, performs poorly over the extended sample that includes the Great Recession.

The hit ratios presented in Figure 2 confirm that, broadly speaking, the best-performing indicators based on RMSEs also tend to perform well at predicting the direction of growth. This is especially the case for composite PMI, which correctly predicts 92 per cent of the current quarter's GDP momentum. Some indicators seem to be particularly good at predicting the direction of the current quarter's GDP growth, such as growth in retail trade and imports, and industrial production of intermediate goods.

For forecasting the euro area's real GDP growth in the next quarter, it seems rather difficult to outperform some of the PMI components, which have a very good track record over 2010 to 2012, but also over a period that includes the Great Recession (2007–12).[17] It is important to note that the RMSEs for the best PMIs for predicting the next quarter's growth (ranging from 0.69 to 0.85) are only slightly larger than the RMSEs of the best PMIs for the current quarter (ranging from 0.69 to 0.79). This is a reflection of the fact that the PMIs are very informative for predicting short-term growth, even two quarters ahead, as highlighted in previous studies. In terms of the hit ratios, in addition to the PMI components, growth in retail trade performs relatively well.

4.2.2 Japan

Turning to Japan, Figures 3a and 3b show the forecast-accuracy results in terms of RMSEs for the current and next quarters, respectively, while Figures 4a and 4b show the hit ratios. The RMSEs of the best indicators for Japan are about three times larger than that for the euro area. At first glance, it appears that indicators in Japan are simply not as accurate at forecasting real GDP growth, although over this period, real GDP growth in Japan is on average 2.9 times more volatile than that in the euro area.[18] In terms of the hit ratio, because of this larger volatility, the direction of growth in Japan seems to be easier to pin down than in the euro area.

For the forecast of the current quarter, Japanese consumption indicators (growth in retail trade, new motor vehicle registrations and the Cabinet Office real consumption index) appear to perform best, both in terms of RMSEs and hit ratios (all above 90 per cent). Some components of the manufacturing PMI and the Economy Watchers Survey (included in "Other surveys" in the figures) also feature a strong performance.

[17] The three components of the PMI index we identify in red are not strictly those with the lowest RMSEs, but are within the top six. They are selected to avoid some overlap, given that the other three components within the top six are variants of these components (e.g., new orders versus new export orders, or stock of finished goods versus orders to inventories).

[18] Over a longer period, from 1999Q1 to 2013Q2, the standard deviation of real GDP quarterly growth (annualized) in Japan is 4.4, but only 2.6 in the euro area.

For the next quarter, the Economy Watchers Survey and some PMI manufacturing components have the lowest RMSEs. Growth in retail trade also seems to do well during the 2010–12 period, but relatively poorly during the Great Recession. The Economy Watchers Survey's hit ratio is rather impressive at 92.5 per cent.

Figure 3. Japan: Individual-indicator RMSE

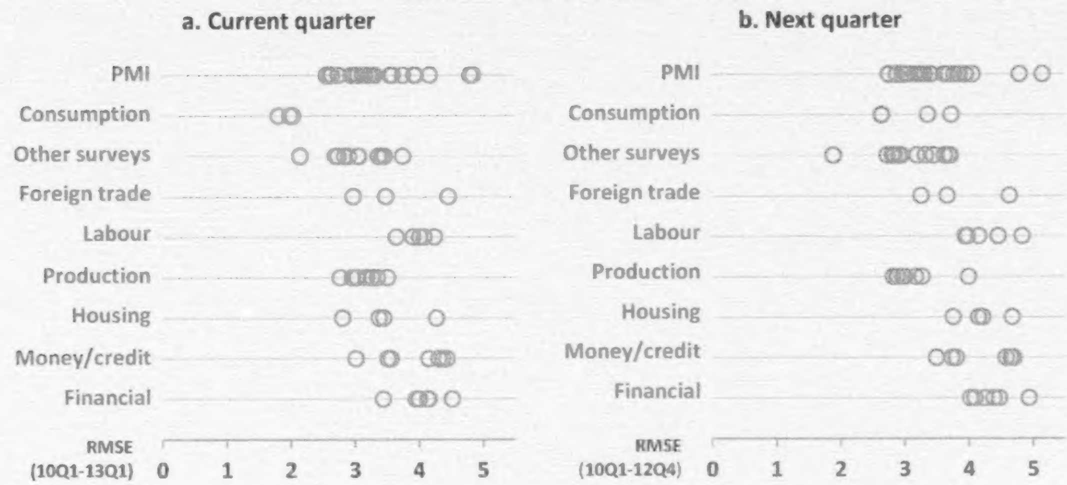
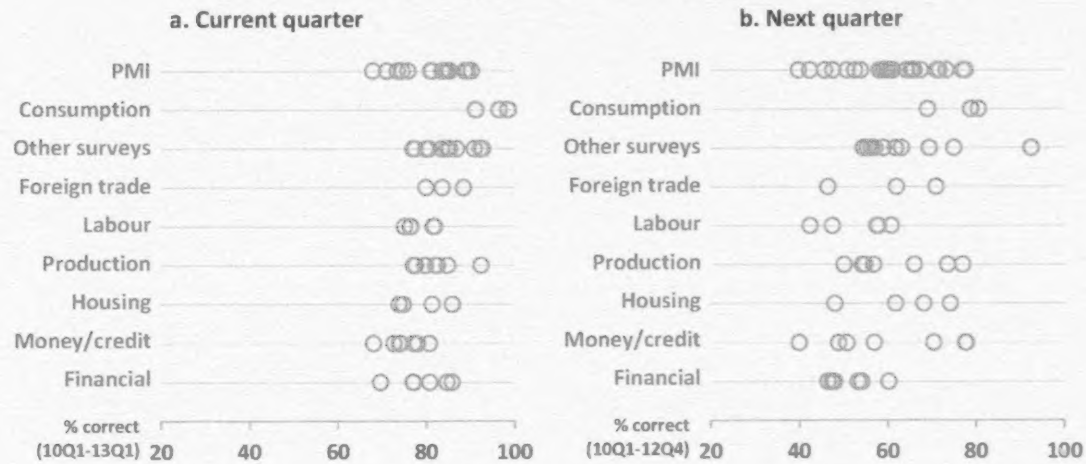


Figure 4. Japan: Individual-indicator "hit ratio"
(% of time that direction of GDP is correctly predicted)

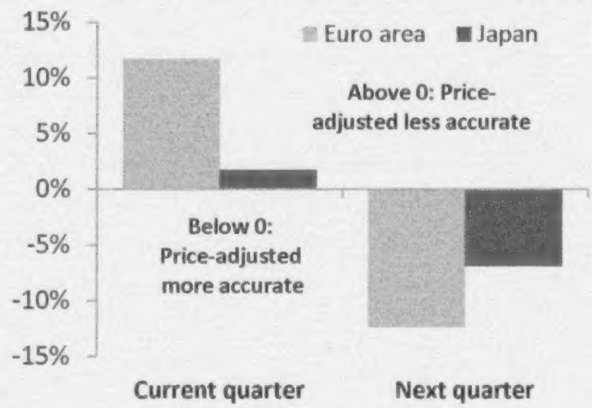


4.2.3 Summary of forecast results

Many of the best-performing indicators for both the euro area and Japan are PMIs, particularly price-adjusted PMIs. In general, price-adjusting PMIs improves the accuracy of the forecast for the next quarter's GDP growth (a median gain of about 7 to 12 per cent), but deteriorates the accuracy of the forecast for the current quarter growth, especially in the euro area (Figure 5).

Figure 5. Price-adjusting PMIs improves the forecast accuracy for the next quarter

Median RMSE: Price-adjusted/Nominal



Relative to other indicators, financial variables and money/credit aggregates do not predict very accurately real GDP growth one or two quarters ahead during the 2010–12 period. During the recession, they perform slightly better, but are outperformed by survey indicators.

5 Forecast combination

Having determined which individual indicators are useful in forecasting short-term real GDP, we now investigate whether we can improve forecast accuracy by combining the predictions from a number of indicators. Several studies have shown that combining predictions from alternative models often improves upon forecasts based on the single best model.[19] Pooling forecasts is a diversification strategy that can produce predictions that are less vulnerable to structural breaks, and also address model misspecification or omitted variable bias. Moreover, combining forecasts can be an effective way to summarize and communicate the implications of several data releases.

Forecast combination approaches include simple averages or more performance-based approaches such as inverse RMSEs and rank-based weights. Kuzin, Marcellino and Schumacher (2013) find that simple averaging often outperforms other, more-sophisticated pooling schemes, when single-indicator MIDAS models are applied to short-term forecasting of GDP growth in six large industrialized countries. Similarly, comparisons by Clark and McCracken (2006) and a survey by Timmerman (2006) show that simple-average combinations are consistently among the best-performing forecasts in a wide range of forecasting situations.

We therefore combine forecasts using simple averages exclusively, mainly because they have been found to be an effective combination method, and they are easy to interpret, communicate and compute in ongoing operations. We first take the simple average of all the individual GDP forecasts that

[19] See Stock and Watson (2004), and Hendry and Clements (2004). Granziera, Luu and St-Amant (2013) review several forecast combination methods and apply them to models currently used at the Bank of Canada.

result from estimating GDP growth with the MIDAS model described above (72 for the euro area, 74 for Japan).

5.1 Preferred forecast combination

We also consider a more parsimonious combination of indicators, which we refer to as our "preferred combination." Based on individual forecast accuracy over the 2010–13 period, we select four to five key indicators, whose forecasts are averaged. We select a separate combination for the current and next quarter forecasts for each economy. The number of indicators entering the forecast combination is somewhat ad hoc, but we find that including more than four or five indicators generally worsens forecast accuracy. We also cross-check these indicators by looking at their individual forecast performance during the recession and their performance in terms of hit ratios, and apply simple economic intuition.[20]

For indicators with many subcomponents (such as the PMI or the ESI), we consider only the indicators' "overall" forecast in the preferred combination. The average prediction of the top three subcomponents is chosen as the "overall" combination, if this combination yields better forecast accuracy than the single-best subcomponent (in terms of RMSE). The forecast from the top subcomponent is otherwise selected. Table 1 shows an example with the ESI, where the average of the top three subcomponents is chosen.

Our preferred combination, with four or five indicators for the current quarter, strikes a balance between forecast accuracy and incorporating a broader range of indicators of economic activity, and simplifies communication of the model results.

Table 1. The average of the forecasts from the top three ESI components is superior to any of the subcomponents

Euro area's ESI	Current quarter's RMSE (2010Q1–13Q1)
ESI - Composite	1.05
ESI - Industrial	1.30
ESI - Services	1.11
ESI - Consumer	0.87
ESI - Construction	0.93
ESI - Retail	1.32
Averaging forecasts of the top three ESI subcomponents (in blue)	**0.71**

5.2 Forecasting performance of a preferred combination of indicators

Table 2 shows the indicators selected to be part of our preferred combinations. For the euro area, four indicators enter the current-quarter forecast, while the next-quarter combination features only three subcomponents of manufacturing PMI, since PMIs significantly outperform other indicators in forecasting the euro area's next quarter GDP growth.

[20] For example, retail sales were excluded from Japan's next quarter forecast, since hard indicators are generally not expected to affect GDP growth beyond the current quarter (from a national accounting perspective), and it performed poorly as an indicator during the recession.

For Japan, our preferred combination for the current quarter includes three consumption indicators, manufacturing PMI (an average of three subcomponents) and the Economy Watchers Survey (firms' current conditions). For the next quarter's forecast, since consumption indicators appear to have little predictive power, only manufacturing PMI (an average of three subcomponents) and the Economy Watchers Survey are included.

Table 2. Preferred combinations of indicators

Euro area	Japan

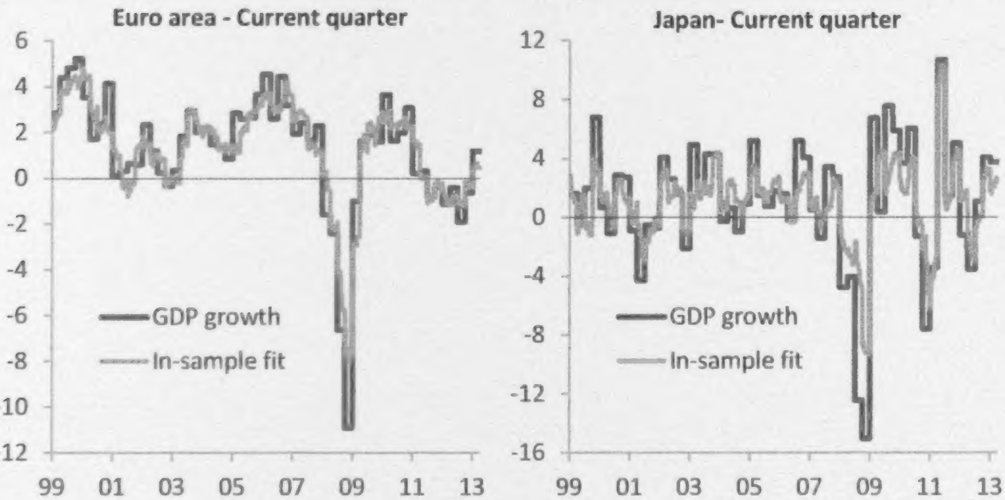
Current quarter
• PMI, average of:
    ○ Composite[21]
    ○ Manufacturing new orders (price-adjusted)
    ○ Services: business activity
• ESI, average of:
    ○ Composite
    ○ Consumer
    ○ Construction
• Eurocoin
• Industrial production (mining/manufacturing)
	Current quarter
	• PMI manufacturing, average of:
	    ○ Output (price-adjusted)
	    ○ Delivery time (price-adjusted)
	    ○ Quantity of purchases
	• Economy Watchers Survey (firms' current conditions)
	• Retail trade
	• New motor vehicle registrations
	• Cabinet Office real consumption index

Next quarter
• PMI manufacturing, average of:
    ○ Stock of finished goods
    ○ New orders (price-adjusted)
    ○ Quantity of purchases (price-adjusted)
	Next quarter
	• PMI manufacturing, average of:
	    ○ Overall (price-adjusted)
	    ○ Output (price-adjusted)
	    ○ New export orders (price-adjusted)
	• Economy Watchers Survey (firms' current conditions)

Figure 6 shows the in-sample fit of our preferred combination for the euro area and Japan over the 1999–2013 period. Overall, our model fits the data well and appears to track the underlying trend in real GDP growth fairly accurately. In both Japan and the euro area, however, the model fails to fully capture the extent of the downturn during the recession. Moreover, the model has difficulty tracking the high volatility inherent in Japanese GDP.

[21] The PMI Composite series was available when the analysis was performed but has since been discontinued. In practice, we now use the composite output index (the headline series) instead.

Figure 6. In-Sample fit – Current quarter



Figures 7 and 8 present the performance of the two combinations of indicators we consider for the euro area: the average prediction across all indicators and our preferred combination. In general, averaging forecasts across *all* indicators reduces accuracy, both relative to our more parsimonious, preferred combination and to the individual performance of the best indicators. For the remainder of the paper, we therefore focus exclusively on our preferred combination, since it shows better properties in terms of out-of-sample performance.

Figure 7. Euro area: RMSE

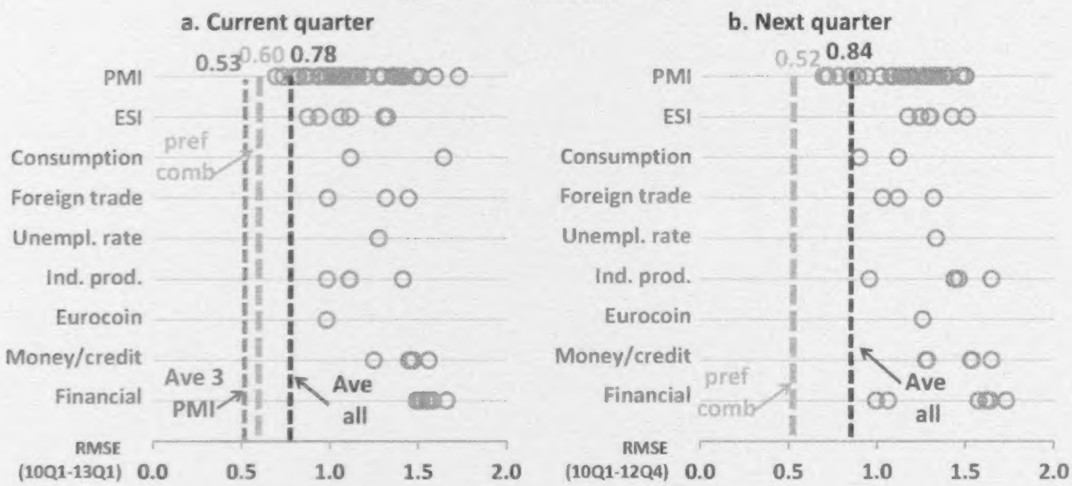
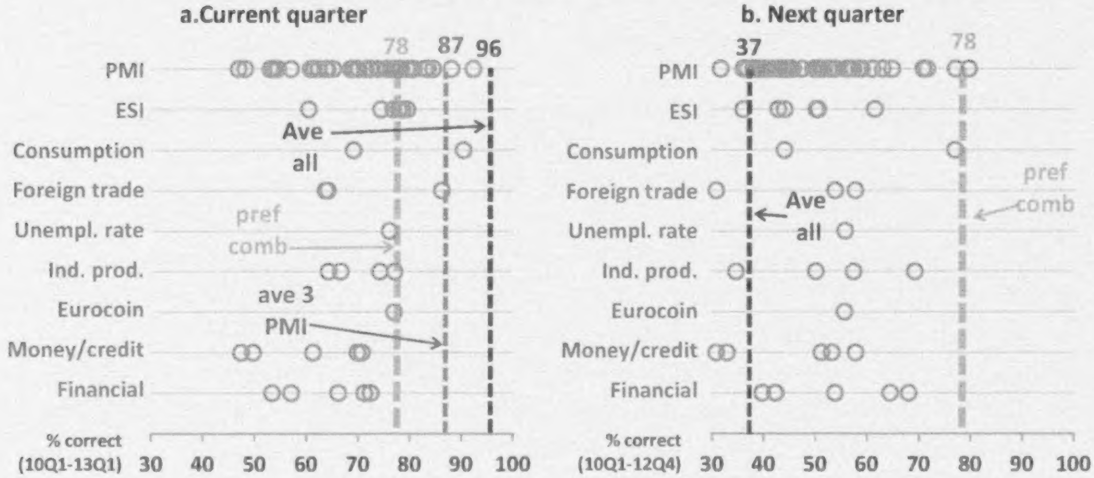


Figure 8. Euro area: "hit ratio"
(% of time direction of GDP is correctly predicted)



For the euro area, our preferred combination is more accurate than any individual indicator for the current quarter, albeit it performs slightly worse than an average of only the three PMI subcomponents with the lowest RMSEs (Figure 7). This deterioration is also apparent in terms of predicting direction (Figure 8). For the next quarter, the preferred combination, which includes only three subcomponents of manufacturing PMI, does considerably better than any individual indicator in forecasting the direction of GDP. Our main finding is that PMIs are simply the best indicators to predict short-term movements in euro-area GDP growth. However, we believe incorporating other indicators of economic activity in the combination can help hedge against possible changes in the relationship between PMIs and GDP growth in the future.[22]

For Japan, our preferred combination also does much better at forecasting GDP growth for both the current and the next quarter than the individual indicators in terms of lower RMSEs (Figure 9). Moreover, the preferred combination predicts the direction of real GDP growth accurately 95 per cent of the time for the current quarter and 90 per cent for the next quarter, compared with about 80 per cent of the time for the average of all indicators (Figure 10).

[22] The importance of incorporating indicators other than PMIs was apparent over the course of 2013, when hard indicators (such as industrial production) generally outperformed PMIs in forecasting euro-area GDP growth.

Figure 9. Japan: RMSE

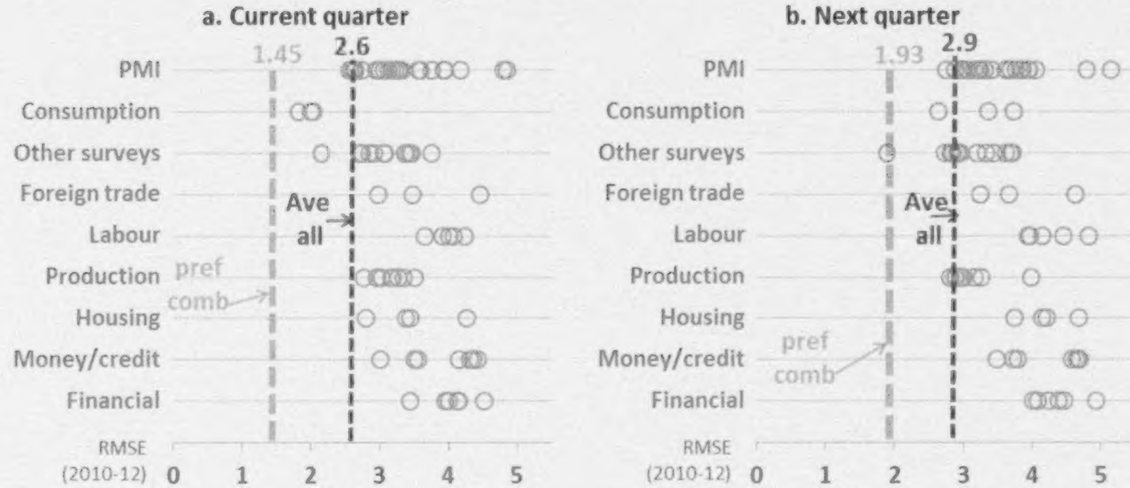
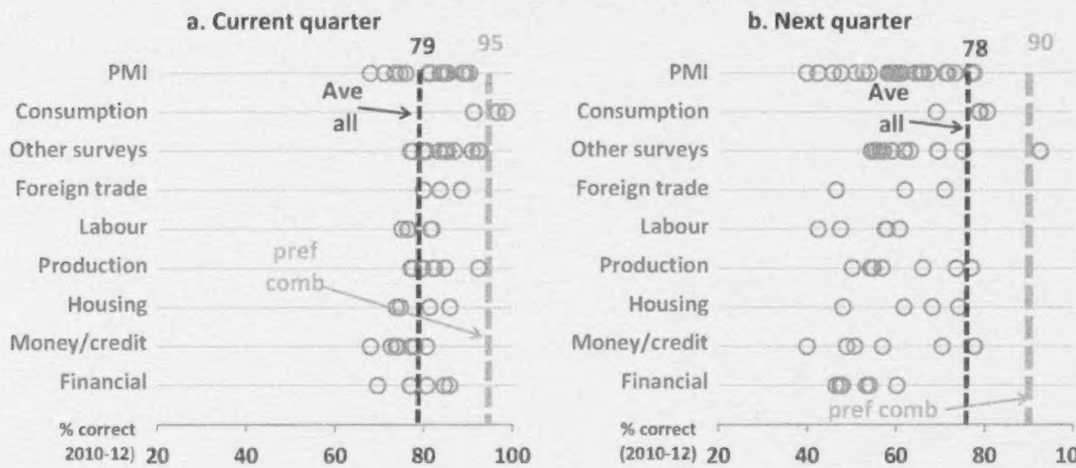


Figure 10. Japan: "hit ratio"
(% of time direction of GDP is correctly predicted)



5.3 The preferred combination and the volatility of the forecast within the quarter

We also investigate whether combining forecasts can help to reduce the volatility of the forecast within a given quarter, as various data are published. A less volatile forecast may reduce the probability of reacting to a false signal coming from the inherent volatility of monthly indicators. Table 3 shows that averaging forecasts of subcomponents and indicators can reduce considerably the average standard deviation of the forecast within a given quarter (compared with, for example, industrial production).

Table 3. Combining forecasts generally reduces forecast volatility within a given quarter

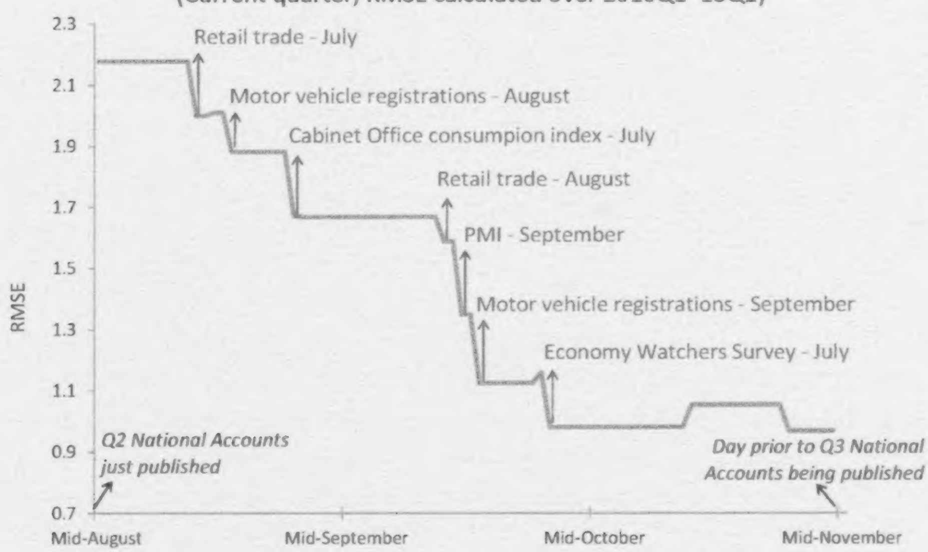
Euro-area indicators	Average standard deviation of the forecast during a quarter (2010Q1–13Q1)
• PMI, average of:	**0.16**
○ Composite	0.28
○ New export orders	0.22
○ Services	0.22
• ESI, average of:	**0.18**
○ Composite	0.19
○ Consumer	0.32
○ Construction	0.30
• Industrial production	**0.44**
• Eurocoin	**0.23**
Preferred combination for the current quarter	**0.14**

5.4 How does the accuracy of our preferred combination evolve over the quarter?

Our forecasting exercise allows for the possibility of obtaining GDP forecasts and evaluation statistics on a daily basis. Figure 11 provides an example of how the Japanese GDP forecast accuracy of our preferred combination evolves during the quarter as the various monthly indicators are published. Overall, as the indicators containing relevant information about real GDP growth are released, the average RMSE gradually declines, by about twofold by the end of the forecast horizon (current quarter). For the euro area (not shown here), the RMSEs are broadly stable over the quarter, reflecting both the large informational content and the early publication of the PMI data.

Figure 11. Evolution of the forecast accuracy of our preferred combination during a given quarter - Japan

(Current quarter, RMSE calculated over 2010Q1–13Q1)



6 Forecast accuracy comparisons and robustness tests

In this section, we compare the forecast accuracy of our preferred U-MIDAS specification with several alternative models using the exact same combination of indicators and sample size as our preferred combination.

We first consider an alternative model specification in which we augment the indicator-based U-MIDAS with an AR(1) process instead of an ARMA(1,1). We also look at two types of commonly used bridge equations: one in which the missing values of the monthly indicators are forecast using an ARMA(1,1) and one that assumes a constant reading in the following months (a "snapshot" approach). We also compare our preferred specification with forecasts from a dynamic factor model in which the data set is the same.[23] Finally, for completeness, we compare our preferred model with naïve benchmarks, such as AR(1) and ARMA(1,1) on quarterly GDP growth. The RMSEs of each model relative to our preferred combination (normalized to 1) are presented in Table 4.

Table 4. Forecast accuracy of preferred combination relative to alternative models
(All models estimated over 1999Q1–2009Q4; RMSE calculated over 2010Q1–13Q1, RMSE of preferred specification = 1.00)

	Euro area		Japan	
	Current quarter	Next quarter	Current quarter	Next quarter
Preferred specification: U-MIDAS – ARMA(1,1)	1.00	1.00	1.00	1.00
U-MIDAS – AR(1)	1.04	1.30††	1.54†††	1.35††
Bridge equation – ARMA(1,1) of indicators	1.26	1.84***	1.91*	2.22**
Bridge equation – Snapshot approach	1.27	1.86***	1.69**	2.30*
Dynamic factor model	1.87***	2.25**	3.56*	3.37*
AR(1) of real GDP growth	2.19†††	2.67†††	3.15†	2.43††
ARMA(1,1) of real GDP Growth	2.40†††	2.94†††	3.13††	2.45†

*,**,***: statistically different from the preferred specification at the 10, 5 or 1 per cent level of significance, respectively, based on a Diebold-Mariano (1995) test.
†,††,†††: statistically different from the preferred specification at the 10, 5 or 1 per cent level of significance, respectively, based on a Clark-West (2007) test (for nested models)

Overall, our preferred specification performs better than any of these alternative models, although the difference from bridge equations is not significant for the euro area for the current quarter. In particular, adding the moving-average term to the U-MIDAS regression improves forecast accuracy, especially for Japan.

Note that the comparison in Table 4 likely favours our U-MIDAS model because the indicators entering our preferred combination were chosen based on their forecasting performance in a U-MIDAS set-up and are therefore not necessarily optimal selections for the alternative models. To assess the importance of this caveat, we look at the correlation between the ranking of all indicators considered (based on their RMSEs) obtained using the U-MIDAS and the two bridge equation procedures. Overall,

[23] The factor model estimated is from Lombardi and Maier (2012).

we find a relatively strong correlation between the rankings, suggesting that the impact from the caveat is likely to be modest.[24]

6.1 Forecast accuracy with real time data and relative to other forecasters

The pseudo out-of-sample forecasting exercise performed with our U-MIDAS model is done using the final vintage of data (i.e., a revised data set), whereas forecasters must use data available in real time. We therefore conduct a sensitivity exercise in which the real GDP growth series used on the left-hand side of our U-MIDAS specification between 2010Q1 and 2013Q1 consists of real-time GDP vintages.[25] As shown in the top two lines in Table 5, using real-time GDP data deteriorates our U-MIDAS forecast accuracy.

We also compare the forecast accuracy of our model with two main private forecasts: Now-Casting.com and the Bloomberg consensus (mean forecast). Our preferred specification outperforms both private sector forecasts by a statistically significant margin.[26, 27]

Table 5. Forecast accuracy relative to private forecasters

(All models estimated over 1999Q1–2009Q4; RMSE calculated over 2010Q1–13Q1, RMSE of preferred specification = 1.00)

Relative RMSE	Real-time data?	Euro area		Japan	
		Current quarter	Next quarter	Current quarter	Next quarter
Preferred specification: U-MIDAS – ARMA(1,1)	No	1.00	1.00	1.00	1.00
Preferred specification: using real-time GDP	Yes	1.48**	1.45*	2.07*	1.92
Now-Casting.com	Yes	2.06*	2.23**	1.76*	2.04*
Bloomberg consensus	Yes	1.97*	2.91**	3.61***	2.69**
Preferred specification: final vintage of GDP, 2006–09 (PMI ave 3)	No	0.88**	1.00	1.60*	1.23
Preferred specification: real-time GDP, 2006–09 (PMI ave 3)	Yes	1.44*	1.45*	3.15*	2.31**

*,**,***: statistically different from the preferred specification at the 10, 5 or 1 per cent level of significance, respectively, based on a Diebold-Mariano (1995) test.

An important caveat is that the indicators in the preferred combination were selected based on their forecast accuracy performance over the 2010Q1–13Q1 period, and then the performance of the

[24] Japan's next quarter forecast is an exception, since it features a low correlation of around 0.7.

[25] Note that only the GDP series is in real time in this sensitivity exercise and the final vintage of data is used for the predictors. However, this does not affect the results for most survey indicators (PMI, ESI, Economy Watchers Survey, etc.), which are given a relatively large weight in the preferred combination.

[26] Now-Casting.com is a website that reports forecasts obtained from large-scale factor models, whose historical forecasts are available for both the euro area and Japan. The model is based on the work of Domenico Giannone and Lucrezia Reichlin. Forecasts from both the Bloomberg consensus and Now-Casting.com are available on a daily basis, so they can be readily compared with daily forecasts coming out of the model.

[27] Using real-time data, Diebold-Mariano tests indicate that RMSEs from our preferred specification and combination of indicators are statistically significantly lower than private sector forecasts for Japan, and for the current quarter euro-area forecast from Now-Casting.com.

combination was evaluated over that same period. We therefore use ex post information that would not have been known to practitioners in real time.[28]

We analyze the sensitivity of our findings to this assumption by choosing the preferred combination based on an out-of-sample forecasting exercise over the 2006–09 period. We then evaluate the combination over the 2010–12Q31 period, using both the final vintage of GDP and the real-time GDP series (bottom lines in Table 5). We find that PMIs outperformed other indicators during the recession, and therefore the preferred combination over the 2006–09 period is simply the average of three PMIs for both countries.

We also conduct exercises to compare the forecast accuracy of our preferred UMIDAS model for GDP growth with that of a bottom-up component-based approach. For the disaggregated approach, we forecast components of real GDP using our preferred combination, and then aggregate these forecasts based on their estimated weight in overall GDP.[29] In this exercise, we evaluate two forms of aggregation: one based on the expenditure components of GDP, and a broader one using only domestic demand and net exports (expressed in contribution to growth).[30] The RMSEs of each approach relative to our preferred combination, which is normalized to one, are presented in Table 6.

Table 6. Forecast accuracy of a component-based disaggregated approach
(Preferred specification = 1.00, RMSE calculated over 2010Q1–13Q1)

	Euro area		Japan	
	Current quarter	Next quarter	Current quarter	Next quarter
Preferred specification (aggregated)	1.00	1.00	1.00	1.00
$Y = C + I + G + X - M + S$	1.31	1.43	1.38**	1.42**
$Y = DD + NX$	0.88	1.50*	1.09*	1.26*

*,**,***: statistically different from the preferred specification at the 10, 5 or 1 per cent level of significance, respectively, based on a Diebold-Mariano (1995) test.

We find that using a disaggregated approach results in a net loss in forecast accuracy relative to the preferred (aggregate) specification, especially for Japan, although the difference is not always statistically significant at even the 10 per cent level. There are, however, some potential gains from using the less aggregated approach of dividing GDP into the subcomponents of domestic demand and net exports, which improves forecast accuracy.

7 Conclusion

This paper describes a new tool that provides short-term forecasts of real GDP growth for the euro area and Japan using unrestricted mixed-data sampling models. This set-up is simple to estimate and

[28] Our choice to limit the evaluation sample to the 2010Q1–13Q1 period reflects the small size of our sample. Also, as mentioned earlier, we did not want the choice of the indicators to be based on the atypical and volatile Great Recession period (2008–09).

[29] The weights of the components were estimated using a simple ordinary-least-squares regression of GDP growth on the components of GDP (inventories are expressed in contribution to growth).

[30] Domestic demand consists of consumption, investment, government spending and inventory investment.

interpret, and allows us to determine which single monthly indicators are best at predicting GDP growth in the short term.

We find that variables in some survey data are very good at forecasting growth two quarters ahead, i.e., when little or no hard data are available, especially the PMI for both the euro area and Japan, and the Economy Watchers Survey in Japan. As we get closer to the publication of the first estimate of real GDP growth, various "hard" data (such as industrial production, consumption and motor vehicle registrations) start to be released. Consequently, in addition to the survey data, we show that forecasts based on some of these data contain useful information in forecasting GDP growth for the current quarter, specifically industrial production and Eurocoin for the euro area, and consumption indicators for Japan.

Using simple averages, we then combine the forecasts from these indicators to construct our short-term forecasting tool. We show that the forecast accuracy from our preferred combination is generally quite good compared with that of any single indicator. It also performs well against various benchmark models and private forecasters, and helps to reduce the volatility of the predictions. Our findings also suggest that there may be some gains in near-term forecast accuracy by using our preferred combination to forecast the domestic demand and net exports subcomponents of GDP instead of aggregate GDP growth. Future work could include further investigation into the possibilities of forecasting GDP growth using a more disaggregated approach.

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Appendix 1. An illustration of the model specification in real time for euro-area GDP

This appendix provides an example of the U-MIDAS model specification in real time with the purchasing managers' index (PMI). In mid-August of a given year, euro-area real GDP growth for the second quarter (Q2) is released and the PMI for July is also available. At this point, the nowcast of GDP growth (labelled "current") is the third quarter (Q3) and the fourth quarter is the forecast. The associated U-MIDAS equations are the following:

$$
\begin{aligned}
Y_{Q3}^{(Q)} = \beta_1^{(M_1)} + \varphi_1 Y_{Q2}^{(Q)} + \gamma_{1,1} PMI_{July}^{(M_1)} + \gamma_{2,1} PMI_{April}^{(M_1)} + \gamma_{2,2} PMI_{May}^{(M_2)} + \gamma_{2,3} PMI_{June}^{(M_3)} + \epsilon_{Q3}^{(M_1)} \\
+ \theta_1^{(M_1)} \epsilon_{Q2}^{(M_1)}
\end{aligned}
$$

$$
\begin{aligned}
Y_{Q4}^{(Q)} = \beta_1^{(M_1)} + \varphi_1 Y_{Q2}^{(Q)} + \gamma_{1,1} PMI_{July}^{(M_1)} + \gamma_{2,1} PMI_{April}^{(M_1)} + \gamma_{2,2} PMI_{May}^{(M_2)} + \gamma_{2,3} PMI_{June}^{(M_3)} + \epsilon_{Q3}^{(M_1)} \\
+ \theta_1^{(M_1)} \epsilon_{Q2}^{(M_1)}
\end{aligned}
$$

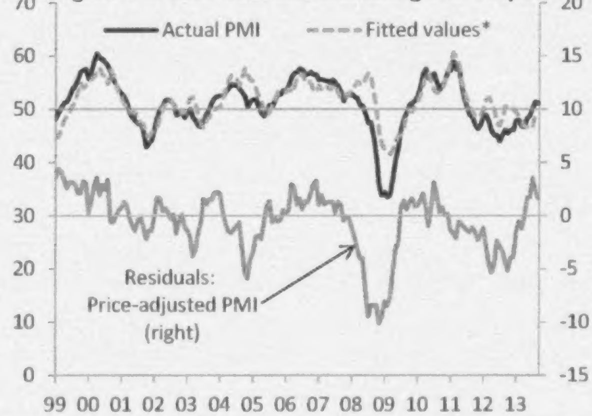
When the value of the PMI for August becomes available at the end of August, it is simply added to the regression. Finally, at the end of September, the six relevant monthly values for the PMI are available (April through September) and included in the regression.

Appendix 2. Price-adjusted purchasing managers' indices (PMIs)

The responses of senior executives to the monthly PMI survey are likely expressed in nominal terms rather than in real terms, since firms' budget decisions are usually made in current dollars. Therefore, for an unchanged production volume but higher input prices, a respondent to the PMI survey may report that the firm's output has improved compared with the previous month, since it has generated more revenues to the firm.

We follow an approach proposed Hatzius et al. (2012) to deflate the U.S. Institute for Supply Management (ISM) index, whereby nominal (or raw) PMI indexes are regressed on the corresponding composite/manufacturing/service input price subcomponent of the PMI survey and a constant. The residuals, which have been purged from the effect of input prices, are then called price-adjusted PMIs (we add back 50 to be comparable with other PMIs).

Figure A-1. Euro-area manufacturing PMI output



*From a regression of PMI manufacturing output on PMI manuf. input prices

Figure A-1 shows an example of the PMI manufacturing output component for the euro area and the fitted values obtained from regressing this index on the PMI manufacturing input prices subcomponent. The adjusted R-squared from this regression is 0.57, which suggests that a large proportion of the variations in PMI reflect price movements. The blue line shows the residuals from the regression that, to a constant close (+50), are the price-adjusted manufacturing output PMI for the euro area. Moreover, we also obtain a relatively high R-squared of more than 0.5 for a majority of PMI manufacturing subcomponents in the euro area, which suggests that many survey participants may base their responses on nominal values for several items.[31]

[31] This is not however the case for PMI services in the euro area or PMI (manufacturing or services) in Japan.

Appendix 3. List of indicators considered for this paper

Legend: L=level, G=monthly growth, D=first difference, pa=price-adjusted PMI series

Euro area

Purchasing managers' index (PMI) - L
- PMI - Composite[32]
- PMI - Composite - Output
- PMI - Composite - New Orders
- PMI - Composite - Employment
- PMI - Composite - Input Prices
- PMI - Manufacturing
- PMI - Manufacturing - Output
- PMI - Manufacturing - New Orders
- PMI - Manufacturing - Employment
- PMI - Manufacturing - Suppliers' Delivery Times
- PMI - Manufacturing - Stocks of Purchases
- PMI - Manufacturing - Quantity of Purchases
- PMI - Manufacturing - Stocks of Finished Goods
- PMI - Manufacturing - New Export Orders
- PMI - Manufacturing - Orders to Inventories
- PMI - Manufacturing - Input Prices
- PMI - Services - Business Activity
- PMI - Services - Employment
- PMI - Services - Prices Charged
- PMI - Services - Incoming New Business
- PMI - Services - Outstanding Business
- PMI - Services - Business Expectations
- PMI - Services - Input Prices
- PMI - Composite (pa)
- PMI - Composite - Output (pa)
- PMI - Composite - New Orders (pa)
- PMI - Composite - Employment (pa)
- PMI - Manufacturing (pa)
- PMI - Manufacturing - Output (pa)
- PMI - Manufacturing - New Orders (pa)
- PMI - Manufacturing - Employment (pa)
- PMI - Manufacturing - Suppliers' Delivery Times (pa)
- PMI - Manufacturing - Stocks of Purchases (pa)
- PMI - Manufacturing - Quantity of Purchases (pa)
- PMI - Manufacturing - Stocks of Finished Goods (pa)
- PMI - Manufacturing - New Export Orders (pa)
- PMI - Manufacturing - Orders to Inventories (pa)
- PMI - Services - Business Activity (pa)
- PMI - Services - Employment (pa)
- PMI - Services - Prices Charged (pa)
- PMI - Services - Incoming New Business (pa)
- PMI - Services - Outstanding Business (pa)
- PMI - Services - Business Expectations (pa)

Economic Sentiment indicator (ESI) - L
- ESI - Overall
- ESI - Industrial
- ESI - Services
- ESI - Consumer
- ESI - Construction
- ESI - Retail

Consumption indicators - G
- Real retail trade
- New motor vehicle registrations

Foreign trade - G
- Real exports (extra euro area)
- Real imports (extra euro area)
- Real net exports (extra euro area)

Unemployment rate - D

Industrial production - G
- Industrial production - total excluding construction
- Industrial production - intermediate goods
- Industrial production - consumer durables
- Industrial production - consumer non-durables

Eurocoin - L

Money and credit - G
- Volume of loans to non-financial corporations
- Volume of loans to households
- Money supply - M1
- Money supply - M2
- Money supply - M3

Financial variables
- Euro nominal effective exchange rate
- Euro real effective exchange rate
- Euro exchange rate with the U.S. dollar
- Share price index
- FTSE 300 price index
- STOXX price index
- STOXX 600 price index

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[32] This series was discontinued after the publication of the paper.

Japan

Purchasing managers' index (PMI) - L
- PMI - Manufacturing
- PMI - Manufacturing - Output
- PMI - Manufacturing - New Orders
- PMI - Manufacturing - Employment
- PMI - Manufacturing - Suppliers' Delivery Times
- PMI - Manufacturing - Stocks of Purchases
- PMI - Manufacturing - Quantity of Purchases
- PMI - Manufacturing - Stocks of Finished Goods
- PMI - Manufacturing - New Export Orders
- PMI - Manufacturing - Backlog of Work
- PMI - Manufacturing - Orders to Inventories
- PMI - Manufacturing - Input Prices
- PMI - Manufacturing - Output Prices
- PMI - Manufacturing (pa)
- PMI - Manufacturing - Output (pa)
- PMI - Manufacturing - New Orders (pa)
- PMI - Manufacturing - Employment (pa)
- PMI - Manufacturing - Suppliers' Delivery Times (pa)
- PMI - Manufacturing - Stocks of Purchases (pa)
- PMI - Manufacturing - Quantity of Purchases (pa)
- PMI - Manufacturing - Stocks of Finished Goods (pa)
- PMI - Manufacturing - New Export Orders (pa)
- PMI - Manufacturing - Backlog of Work (pa)
- PMI - Manufacturing - Orders to Inventories (pa)

Consumption indicators - G
- Cabinet Office real consumption index
- Real retail trade
- New motor vehicle registrations

Other surveys - L
- Economy Watchers Survey - Current Conditions
- Economy Watchers Survey - Future Conditions
- Economy Watchers Survey - Current Cond. Households
- Economy Watchers Survey - Future Cond. Households
- Economy Watchers Survey - Current Cond. Corporations
- Economy Watchers Survey - Future Cond. Corporations
- Shoko Chukin - Business conditions index
- Shoko Chukin - Manufacturing
- Shoko Chukin - Non-manufacturing
- Shoko Chukin - Finished goods inventory
- Shoko Chukin - Production capacity
- Shoko Chukin - Sales index
- Consumer Confidence (2+ person households)

Foreign trade - G
- Real exports
- Real imports
- Real net exports

Labour markets - G
- Employment
- Unemployment rate
- Total gross earnings (5+ employees)
- Contractual earnings (5+ employees)
- Real earnings index (5+ employees)

Production indicators - G
- Industrial production - Mining and manufacturing
- Industrial production - Investment goods
- Industrial production - Consumer goods
- Industrial production - Producer goods
- Industrial production - Final-demand goods
- Producers' shipments (mining/manufacturing)
- Producers' inventory (mining/manufacturing)
- Inventory/sales ratio (mining/manufacturing)
- Motor vehicle production

Housing markets - G
- Housing starts - floor area
- Housing starts - units
- Residential building permits - floor area
- Residential building permits - value

Money and credit - G
- Volume of loans to non-financial corporations
- Volume of loans to households
- Money supply - M1
- Money supply - M2
- Money supply - M3

Financial variables - G
- Exchange rate with the U.S. dollar
- JP Morgan broad real effective exchange rate
- JP Morgan broad nominal effective exchange rate
- Nikkei stock exchange (TSE 225)
- Tokyo stock price (TOPIX)
- Crude oil prices (Dubai)
- Monetary base
- Bank of Japan total assets

Appendix 4. Detailed out-of-sample forecast accuracy results

Legend: pa=price-adjusted PMI series

Euro area

Indicators	RMSE*		Hit ratio (%)	
	Current	Next	Current	Next
PMI - Composite	0.690	1.254	92.2	58.3
PMI - Composite - Output	0.937	1.186	84.5	56.4
PMI - Composite - New Orders	0.930	1.305	80.7	39.2
PMI - Composite - Employment	1.349	1.079	60.8	36.0
PMI - Composite - Input Prices	1.007	1.467	73.7	35.9
PMI - Manufacturing	1.291	1.394	61.4	31.6
PMI - Manufacturing - Output	0.969	1.332	69.1	37.9
PMI - Manufacturing - New Orders	1.069	1.274	64.1	38.3
PMI - Manufacturing - Employment	1.107	1.280	70.0	51.3
PMI - Manufacturing - Suppliers' Delivery Times	1.141	1.158	69.9	56.5
PMI - Manufacturing - Stocks of Purchases	1.269	1.084	79.5	63.0
PMI - Manufacturing - Quantity of Purchases	1.025	1.157	78.3	50.8
PMI - Manufacturing - Stocks of Finished Goods	1.397	0.693	69.2	64.7
PMI - Manufacturing - New Export Orders	0.787	1.322	77.0	53.8
PMI - Manufacturing - Orders to Inventories	1.002	1.143	72.5	47.3
PMI - Manufacturing - Input Prices	0.971	1.471	77.6	45.6
PMI - Services - Business Activity	0.794	1.497	83.4	57.2
PMI - Services - Employment	1.154	1.256	69.9	39.8
PMI - Services - Prices Charged	1.386	1.165	72.3	41.5
PMI - Services - Incoming New Business	0.933	1.494	77.4	43.7
PMI - Services - Outstanding Business	1.191	1.125	83.5	77.0
PMI - Services - Business Expectations	1.126	1.319	73.8	52.8
PMI - Services - Input Prices	1.370	1.254	57.0	50.0
PMI - Composite (pa)	1.135	1.086	49.0	47.3
PMI - Composite - Output (pa)	1.057	0.938	62.3	58.9
PMI - Composite - New Orders (pa)	0.866	1.074	71.4	49.7
PMI - Composite - Employment (pa)	1.504	1.252	54.4	38.6
PMI - Manufacturing (pa)	1.007	0.888	65.1	53.4
PMI - Manufacturing - Output (pa)	1.027	1.016	77.2	56.0
PMI - Manufacturing - New Orders (pa)	0.860	0.777	80.4	58.3
PMI - Manufacturing - Employment (pa)	1.724	1.167	48.1	49.5
PMI - Manufacturing - Suppliers' Delivery Times (pa)	1.357	1.384	53.0	45.0
PMI - Manufacturing - Stocks of Purchases (pa)	1.483	1.096	69.2	53.6
PMI - Manufacturing - Quantity of Purchases (pa)	0.811	0.845	82.9	71.5
PMI - Manufacturing - Stocks of Finished Goods (pa)	1.416	0.717	73.7	64.7
PMI - Manufacturing - New Export Orders (pa)	0.713	0.775	92.5	70.8
PMI - Manufacturing - Orders to Inventories (pa)	0.813	0.710	75.4	79.7
PMI - Services - Business Activity (pa)	0.966	1.208	70.0	45.6

Indicators	RMSE*		Hit ratio (%)	
	Current	Next	Current	Next
PMI - Services - Employment (pa)	1.290	1.113	46.8	43.0
PMI - Services - Prices Charged (pa)	1.591	1.387	53.7	40.4
PMI - Services - Incoming New Business (pa)	1.291	1.346	63.7	36.7
PMI - Services - Outstanding Business (pa)	1.409	1.178	68.5	50.0
PMI - Services - Business Expectations (pa)	1.095	1.330	76.3	52.5
ESI - Overall	1.061	1.284	76.7	51.3
ESI - Industrial	1.307	1.253	73.9	54.9
ESI - Services	1.111	1.294	79.5	50.5
ESI - Consumer	0.870	1.421	78.6	42.7
ESI - Construction	0.972	1.477	78.4	44.0
ESI - Retail	1.319	1.172	60.4	35.9
Real retail trade	1.171	0.951	90.4	76.9
New motor vehicle registrations	1.641	1.117	69.1	44.0
Real exports (extra euro area)	1.314	1.117	64.1	53.8
Real imports (extra euro area)	0.984	1.027	86.2	57.7
Real net exports (extra euro area)	1.442	1.317	63.7	30.8
Unemployment rate	1.374	1.497	72.1	53.2
Industrial production - total ex. construction	0.982	1.435	66.7	50.1
Industrial production - intermediate goods	1.109	1.645	77.1	34.6
Industrial production - consumer durables	1.412	1.461	64.3	57.4
Industrial production - cons. non-durables	1.108	0.954	74.2	69.2
Eurocoin	0.980	1.258	77.0	55.6
Volume of loans to non-financial corporations	1.471	1.277	49.7	30.8
Volume of loans to households	1.249	1.284	70.0	57.8
Money supply - M1	1.559	1.531	70.8	32.9
Money supply - M2	1.448	1.647	47.4	53.2
Money supply - M3	1.468	1.536	61.4	51.2
Euro nominal effective exchange rate	1.548	0.995	57.1	68.1
Euro real effective exchange rate	1.584	0.995	57.1	64.5
Euro exchange rate with the U.S. dollar	1.661	1.063	53.4	53.8
Share price index	1.498	1.575	72.5	39.7
FTSE 300 price index	1.520	1.641	72.5	42.4
STOXX price index	1.491	1.618	71.3	42.4
STOXX 600 price index	1.555	1.732	66.2	42.2
Ave 3 PMI	0.525	0.524	86.1	78.4
Ave 3 ESI	0.699	1.231	76.7	45.8
Preferred combination	0.595	0.524	77.7	78.4
Average of all indicators	0.781	0.840	96.3	37.0

*The root mean square errors (RMSEs) are calculated on quarter-over-quarter annualized growth rates and are in basis points. The sample period for calculating the RMSEs is 2010Q1–13Q1 for the current quarter and 2010Q1–12Q4 for the next quarter.

Japan

Indicators	RMSE*		Hit ratio (%)	
	Current	Next	Current	Next
PMI - Manufacturing	2.996	3.256	83.6	61.1
PMI - Manufacturing - Output	2.642	3.014	88.8	73.3
PMI - Manufacturing - New Orders	2.946	3.402	85.3	50.8
PMI - Manufacturing - Employment	3.558	3.624	81.0	67.5
PMI - Manufacturing - Suppliers' Delivery Times	3.116	3.312	71.1	47.6
PMI - Manufacturing - Stocks of Purchases	3.589	3.941	84.7	52.6
PMI - Manufacturing - Quantity of Purchases	2.612	3.317	81.3	66.0
PMI - Manufacturing - Stocks of Finished Goods	4.838	4.789	75.9	39.8
PMI - Manufacturing - New Export Orders	3.295	2.969	84.2	71.6
PMI - Manufacturing - Backlog of Work	3.264	3.957	88.8	58.1
PMI - Manufacturing - Orders to Inventories	3.288	3.834	73.5	58.4
PMI - Manufacturing - Input Prices	3.923	3.683	83.6	71.1
PMI - Manufacturing - Output Prices	3.311	3.854	84.7	65.3
PMI - Manufacturing (pa)	3.048	2.875	75.9	71.6
PMI - Manufacturing - Output (pa)	2.560	2.749	81.0	77.5
PMI - Manufacturing - New Orders (pa)	3.161	3.153	73.5	59.9
PMI - Manufacturing - Employment (pa)	4.164	4.055	84.5	60.7
PMI - Manufacturing - Suppliers' Delivery Times (pa)	2.601	3.051	81.0	67.5
PMI - Manufacturing - Stocks of Purchases (pa)	3.746	3.611	74.6	45.7
PMI - Manufacturing - Quantity of Purchases (pa)	2.741	3.219	90.2	64.3
PMI - Manufacturing - Stocks of Finished Goods (pa)	4.802	5.148	75.9	42.4
PMI - Manufacturing - New Export Orders (pa)	3.224	2.968	89.4	77.0
PMI - Manufacturing - Backlog of Work (pa)	3.944	3.683	67.9	59.2
PMI - Manufacturing - Orders to Inventories (pa)	3.264	3.770	73.5	53.9
Cabinet Office real consumption index	2.028	3.359	91.2	80.5
Real retail trade	1.807	2.641	96.5	78.8
New motor vehicle registrations	1.989	3.725	98.5	69.0
Econ. Watchers Survey - Current Conditions	2.695	2.728	77.4	75.0
Econ. Watchers Survey - Future Conditions	2.840	2.807	85.3	57.1
Econ. Watchers Survey - Current Cond. Hholds	2.724	2.913	84.6	69.4
Econ. Watchers Survey - Future Cond. Hholds	2.738	2.843	92.7	55.4
Econ. Watchers Survey - Current Cond. Corpo.	2.145	1.886	92.2	92.5
Econ. Watchers Survey - Future Cond. Corpo.	3.364	2.954	79.9	54.6
Shoko Chukin - Business conditions index	2.903	2.919	84.7	63.2
Shoko Chukin - Manufacturing	3.465	3.448	84.7	59.1
Shoko Chukin - Non-manufacturing	3.048	3.193	77.0	61.8
Shoko Chukin - Finished goods inventory	3.747	3.626	86.9	56.4
Shoko Chukin - Production capacity	3.426	3.690	90.9	54.4
Shoko Chukin - Sales index	3.375	3.715	83.5	69.5

Indicators	RMSE*		Hit ratio (%)	
	Current	Next	Current	Next
Consumer Confidence (2+ person hhlds)	3.065	3.328	80.6	61.9
Real exports	2.972	3.253	88.4	62.0
Real imports	4.454	4.632	79.9	46.5
Real net exports	3.480	3.663	83.6	71.0
Employment	4.075	4.454	76.5	42.5
Unemployment rate	3.644	3.939	81.9	57.9
Total gross earnings (5+ employees)	4.235	4.151	76.3	47.5
Contractual earnings (5+ employees)	3.903	4.828	75.1	57.6
Real earnings index (5+ employees)	4.009	3.975	81.6	60.8
Industrial production - Mining/manufacturing	3.170	2.818	82.2	54.4
Industrial production - Investment goods	3.185	3.002	77.5	66.1
Industrial production - Consumer goods	2.958	2.893	84.8	54.7
Industrial production - Producer goods	3.265	2.964	82.5	73.6
Industrial production - Final-demand goods	3.351	2.970	77.1	54.9
Producers' shipments (mining/manuf.)	3.507	2.879	77.5	50.2
Producers' inventory (mining/manuf.)	2.962	3.170	92.4	77.0
Inventory/sales ratio (mining/manuf.)	3.031	3.995	79.8	54.3
Motor vehicle production	2.773	3.270	79.7	56.8
Housing starts - floor area	3.447	4.148	74.8	68.2
Housing starts - units	2.804	3.753	85.9	61.8
Residential building permits - floor area	4.269	4.675	73.8	48.1
Residential building permits - value	3.377	4.218	81.4	74.2
Volume of loans to non-financial corporations	4.367	4.656	68.0	50.8
Volume of loans to households	4.148	4.579	74.2	57.0
Money supply - M1	4.431	4.700	72.7	40.0
Money supply - M2	3.562	3.733	80.7	77.8
Money supply - M3	3.513	3.493	73.8	77.6
Exchange rate with the U.S. dollar	3.441	4.025	84.6	53.3
JP Morgan broad real effective exch. rate	3.950	4.091	80.8	46.5
JP Morgan broad nominal effective exch. rate	3.998	4.252	77.1	47.4
Nikkei stock exchange (TSE 225)	4.152	4.475	77.0	47.9
Tokyo stock price (TOPIX)	4.136	4.936	85.8	60.3
Crude oil prices (Dubai)	4.515	4.392	69.6	54.1
Monetary base	3.015	3.799	78.0	70.5
Bank of Japan total assets	4.305	4.685	77.1	48.9
Ave 3 PMI	2.325	2.021	81.3	91.6
Preferred combination	1.447	1.927	94.5	90.0
Average of all indicators	2.637	2.916	79.1	78.2

*The root mean square errors (RMSEs) are calculated on quarter-over-quarter annualized growth rates and are in basis points. The sample period for calculating the RMSEs is 2010Q1–13Q1 for the current quarter and 2010Q1–12Q4 for the next quarter.